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COLLABORATIVE ACTIVE ROOF DESIGN

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1. Introduction

Roofs play an essential role in buildings. Their value and impact often significantly surpass the cost ratio they represent in the total investment cost of the building. Traditionally, roofs have a protecting function and their basic design has changed little over hundreds of years. Nowadays however, they are increasingly used as preferred location for mounting additional functions such as photovoltaic systems, roof lights, ventilation devices, insulation and safety devices. The roof will contain more and more aspects which are strongly related with the comfort of the building as a whole. Looking in a wider context, the build environment is dominated by the circumstances related to energy use. A wide variety of new products, such as photovoltaic (PV) systems and solar collectors, roof lights, ventilation devices and insulation are introduced as adaptable elements related to the roof. Many problems arouse in implementing these products or combinations of products into the total roof, the roofing industry and the integration into the building design. Introduction of a broader variety of products causes a more complex process of designing and engineering, to be organized and developed with more participants with different backgrounds. These recent developments lead in practice up to a number of sticking points:
- The new products have been seldom developed on the roof to be applied. For this reason there are no uniform standards and building specific performance assess. For this reason frequently own solutions are developed, which have to be adapted on the site itself.
- Good products are installed by not-qualified people. This leads to leakage caused by rain or snow, but also to wind damage and condensation problems.

Within the EU the total amount of failure-costs arouse to approximately 2 billion Euros per year. The secondary damage to the interior of the build environment is at least of same the size order. The majority of these claims can be prevented if adequate standards and directives for tests and installation existed. European roofers will be faced with a rising number of claims as these problems will not be solved. Although there is specific knowledge, within the roofer industry, concerning how a roof must be made, the roofer should be more active and anticipating on these developments. The added value of this knowledge, should be incorporated on the right moment of the design. In the concept phase of the building design the most important decisions have to be made in order to optimize the final result. At this stage of the process many of the construction- and user-aspects should be implemented in order to optimize the final building product and to reduce failure costs and damage to the roof, during the user phase (Fig. 1).

There exists a gap between solutions and application in design practice of active roofs (EURACTIVE ROOF-er, 2005). Roof design and roof engineering with all its existing – traditional – and new functions and applications are most of the time handled like separate and add-on aspects. As complexity and scale of design processes in architecture and in building services engineering increase, as well as the demands on these processes with respect to costs, throughput time and quality, traditional approaches to organize and plan these processes may no longer suffice (van Aken 2005).

This implies defining a process methodology that acts as a "bridge" between architectural elements such as shapes and material on the one hand, and the aspects of indoor climate issues such as overheating and ventilation on the other; an integral approach where all design members have shared understanding – with their own background – on the project. The 6th framework Pan- European EUR-ACTIVE ROOFer project aims at development of a methodology for supporting not only the architect but the whole design team in the early phase of the design process on integrating active roofs – as energy generating integrated building components – in relationship with the product development of the active roof itself.

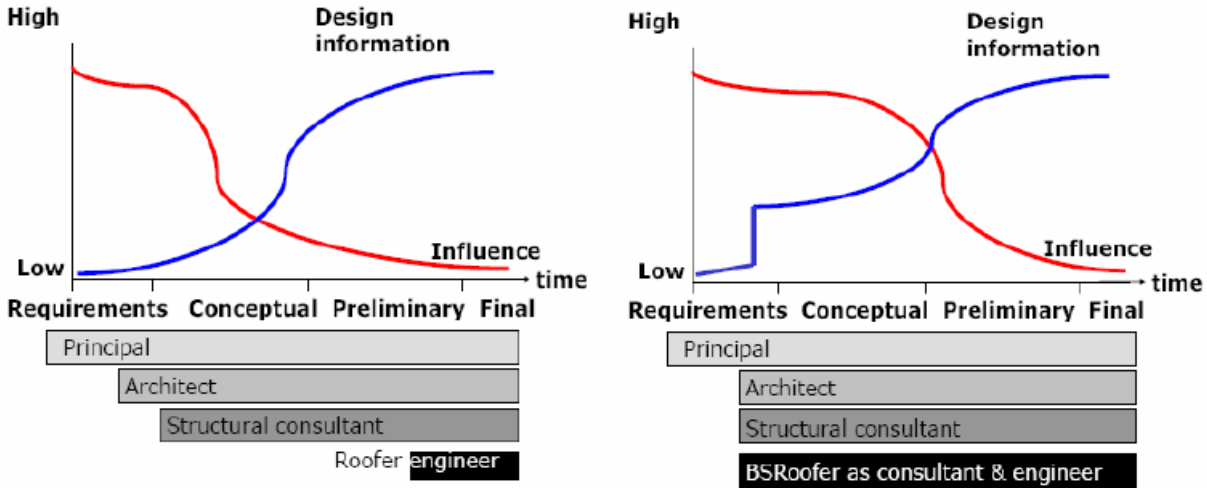

Figure 1. Relationship between Design Information and Influence

To improve the roof design a supportive process approach that stimulates collaboration between Architect and Roofer is needed. Such a design process for the design of a (new) product is called a Collaborative Design (Bento et al., 2004). Within such a setting, participants like Architects and Roofers, differ in cultural backgrounds, their way of working, and have a different motivation of collaboration (Korbijn, 1999). Development of innovative products need an optimal exchange and development of the different knowledge types. To come to new products these different knowledge-types have to be exchanged and developed more optimal. Van Aken (2005) distinct between object-knowledge related to designers (Architects), and realization-knowledge related to contractors (Roofers). Object knowledge can be defined as knowledge on the characteristics and properties of artefacts and their materials as used by Architects, where realization knowledge is knowledge on the various physical processes to be used to realize designed artefacts, used by for instance Roofers (van Aken 2005). Both types of knowledge are communicated within the collaboration between Architect and Roofer, with different educational backgrounds and with large differences in competences and skills, through different kinds of representation (Brereton, 1998). Related to the type of knowledge and the team-collaboration between architect and roofer the focus will be on explicit 'object and realization knowledge' (van Aken 2005). This focus generates the information which makes clear how the contribution of the discipline based object knowledge and realization knowledge is communicated and how this knowledge is transformed into the design concepts (see Figure 2).
During the period of 2006-2009 a workshop as method to train Collaborative Design Teams was developed as part of the Dutch Program for Permanent Education for Professionals. This Collaborative Design Workshop has to stimulate members of collaborative design teams, Architects, Roofers and Installers, to share, use and develop collectively specific information of innovative – active – roofs. The aim of the workshop model is to support design activities by the use of a specific design method – Morphological Overviews - for the design process to structure information and knowledge exchange between and with commitment of all participants to optimize design solutions. This paper desicribes generally the the methodolgogy for the design of the workshop and more specific one step in this design; the experimental setting of the Brakel-Atmos-workshop. Finally the first results are shown and discussed as part of the next step in the design-phase for the final workshop-setting.

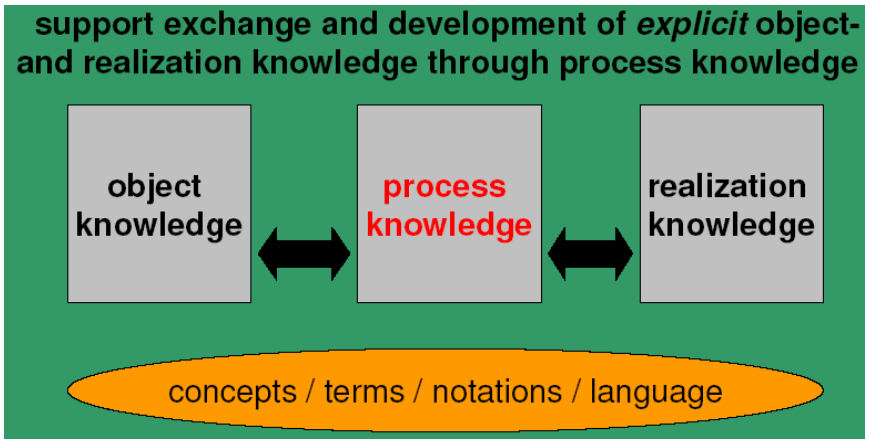

Figure 2. Process knowledge to connect object knowledge and realization knowledge

2. Methodology

The research is strongly related to the problems and needs form practice. Although Collaborative Design teams are working in practice due to all variables in task-type and time makes that – as a researcher – looking at the real world will not offer the circumstances to compare. Therefore an experimental setting has to be developed which is as precise as possible both to the professionals as team members of the Collaborative Design team, as well as for the researcher. Related to the type of research – technological design – an appropriate methodology is necessary to design the setting as well as the analysing method(s) needed. The main method and methodology used are the Methodical Design model [Van den Kroonenberg and Siers, 1992] and the Design Research Methodology [Blessing and Chakrabarti, 2001 and 2009].

The DRM consists of four stages: research clarification, a Descriptive study 1, a Prescriptive study and a second Descriptive study. Not every stage of the methodology will be excecuted in depth because of practical aspects such as limited resources. This paper focuses on the second stage, the Descriptive study 1, which emphasizes the need to increase the understanding of the aspects related to the specific design-setting as an experiment; the Collaborative Design Workshop. Through design a first Collaborative Design Workshop with specific characterics and analysing the setting related to specific aspects necessary to work as a practical and research setting, the next setting is defined. The role of the Descriptive Study 1 stage is:

- to identify the factors that influence the formulated criteria and how they influence thes
- to provide a basis for the development of the setting to improve
- to provide more details that can be used to evaluate the development.

Since the early seventies there was a period of expansion of the development of design methods through the 1990s right up to day: design as a coherent discipline of study was definitely established in its own right [Cross, 2007]. Still there is no clear picture [Horváth, 2004, Bayazit 2004] and many models of designing exist [Cross, 1994, Wynn and Clarkson, 2005, Pahl et al., 2006]. That makes it difficult to choose and implement design models in practice. Methodical design was chosen as a starting point of development because it has exceptional characteristics [Blessing, 1994]: it is a problem-oriented model; it is one of the few models that explicitly distinguishes between strategies, stages and activities; it is the only model that emphasizes the execution of the process at every level of abstraction. Methodical Design is based on system theory and a combination of ideas of the German design school of Pahl, Beitz and others and the Anglo-American's: Archer, Greogory, Krick, Jones and others [Blessing, 1994]. Methodical Design combines German and Anglo-American process model approaches. Methodical Design is a problem oriented model based on functional hierarchy, which can be applied on several levels of abstraction and makes it possible to link these levels of abstraction with the phases in the design process itself. Characteristics of the design process are split into; strategies, stages and activities. Within the setting of Methodical Design several design-support tools are used to structure several functionalities, generate and select possible solutions and can be used for different aspects and abstraction levels.

Methodical Design is extended into Integral Design (ID) by adding a new phase related to the decision making and selecting process steps [Savanovic, 2009]. Due to these characteristics ID can accommodate different subjective interpretations of design requirements, inherent to the approach of the different design team members. By structuring the requirements, within each complexity level, development of a shared understanding in the design team is encouraged. More insight in different possibilities based on the design requirements by the design-team-members, can generate more possible solutions. Through an iteration cycle of interpretation-generation steps the set of requirements is continuously refined, and with it also the design solution proposals. The research is focused on the added value of the introduced design-tools, especially the morphological overview, as part of ID, within the collaborative design team for the preliminary design-phase.

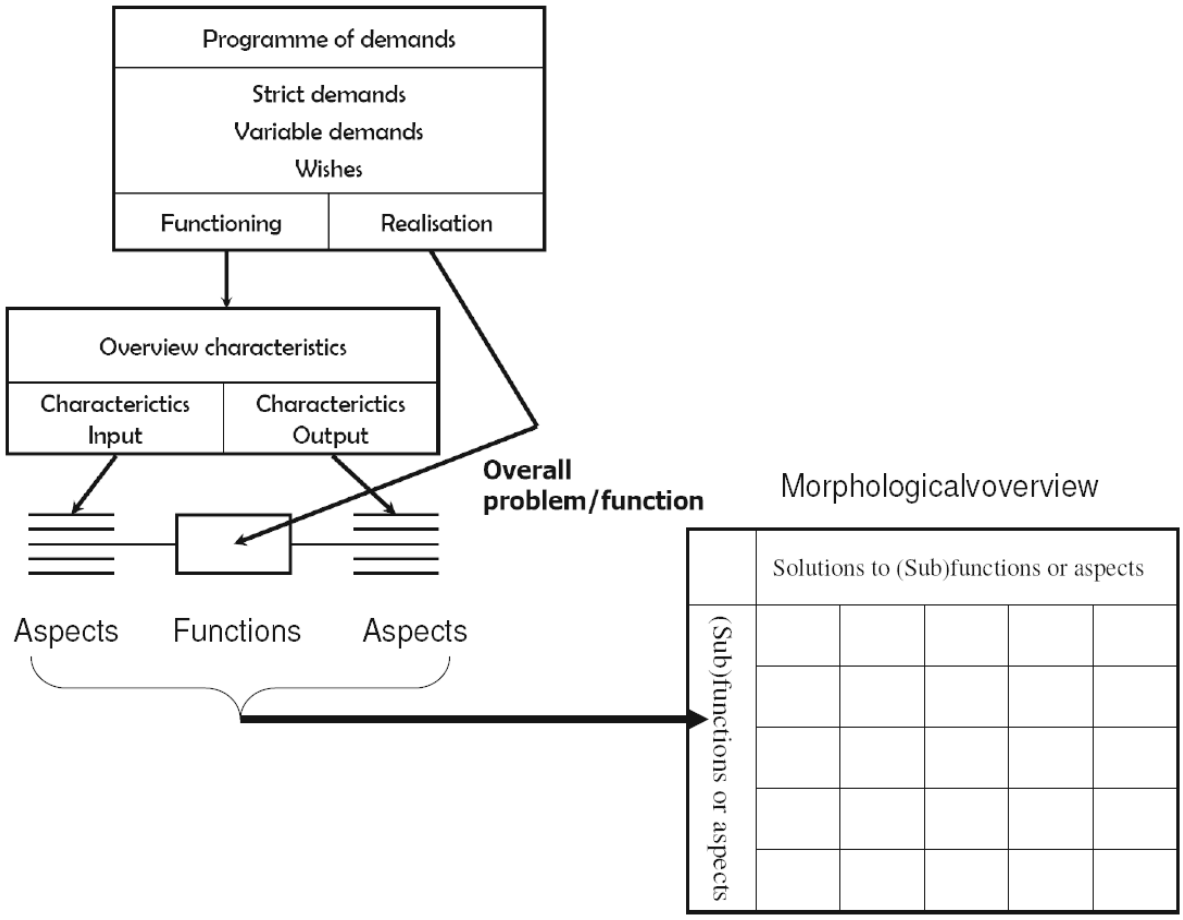

Figure 3. The transformation from the program of demands into a morphological overview

During the design process, and depending on the focus of the designer, functions exist at the different levels of abstraction. Morphology provides a structure to give an overview of the functions considered and the alternative solutions. General Morphological analysis was developed by Fritz Zwicky [Zwicky and Wilson, 1967] as a method for investigating the totality of relationships contained in multi-dimensional, usually non-quantifiable problem complexes [Ritchey, 2002]. Essentially, general morphological analysis is a method for identifying and investigating the total set of possible relationships or "configurations" contained in a given problem complex.
The main aim of this method is to widen the search area for possible new solutions [Cross, 1994]. Morphology provides a structure to give an overview of the considered functions and aspects and their solution alternatives. Transforming the program of demands into characteristics for input and output (aspects) and formulation of the different relations between input and output (functions) to fulfil, leads to the construction of a morphological overview, see figure 3.

3. Collaborative Design Workshops as experimental setting

Related to research on Collaborative Design theory, as the way to describe the nature of it, two different approaches are recognized [Achten, 2009]; the way Collaborative Design should be managed, or how it distinguishes itself from other types of design. Our research is concerned with how to achieve Collaborative Design in order to enrich the design with object- and realization knowledge. Until now there is no consensus how this may be achieved [Achten, 2009]. Related to research on training Collaborative Design two main approaches are detected (van Achten, 2009); Pedagogical Models and Virtual Design Studios. For pedagogical models, similarly to the situation in design studio work, 'learning by doing' [Schön, 1993] is the predominant pedagogy. Much of the work in the field is technology driven, but there is a strong tendency not do any 'reality-check' how much of the work is applicable in practice, or to see what actual the demands from practice are [van Achten 2009, p. 362].
The methodology used for the development of the Collaborative Design Workshops is comparable to a design of this setting with iterative design steps related to analysis, selecting and shaping the set-up of the workshops. The results of the previous workshop led to the requirements of the next workshop. To describe the development of the model for the Collaborative Design Workshop we use for each step in this development five criteria; the characteristics of the method to train participants in a Collaborative Design-setting. These criteria are; aim or outline, steps within the development, evaluation, communication and testing. At the end of each workshops there was an evaluation part; the participants / design teams could present and discuss their designs, the collaboration related to the workshop setup and the use of the design method. Through a predefined questionnaire the participants could reflect on the set up of the workshop and the introduced support tool (Morphological Overviews).
The experiments [Yin, 1994], 'workshops' were held with professionals of the different involved disciplines designers and roofer engineers, with focus on the following aspects:

- communication between the design- and engineering solutions for active roofs
- generation of more possible design / engineering solutions for active roofs
- the use of the support decision tool to generate these design / engineering solutions

The experiments have the format of design task workshops and/or master classes related to design tasks. As example, related to the setting of workshops and the use of ID tools we can define the following functionalities / needs related to these experiments:

- situation of the design-team without the use of methodical design tools
- situation of design team by using methodical design tools

To distinguish the knowledge-exchange aspects related to the use of the tools of ID, several views are used to extract data out of design teams: by evaluation-questionnaires for all participants, photographs of the produced items by the team and video-registration / analysis of the experiments.

Set up of the workshops

The workshops were held in 2007, in-company and with professionals with different educational backgrounds. The company (Brakel Atmos) is a specialist in fire safety engineering, especially roof integrated smoke exhaust systems. The set-up of the workshop is given in figure 4 and 5. Participants were designers, engineers/constructors and users/clients. The participants, 9 in total, were devided into 3 groups according to the schemes of the set-ups. All participants were male and had on average more than 10 years experience. All the same participants participated in the workshops series 1 and 2, though in different team setting. In figure 4 and 5 the Design group members are marked by an O, the building group members by an U and the usersgroup by a G.
The question we focused on during the workshops was whether knowledge-development would take place between the different participants and if the introduction of the Morphological Overview is as felt as helpful by the participants. The participants had to fill in a questionnaire directly afterwards the workshops about their experiences.

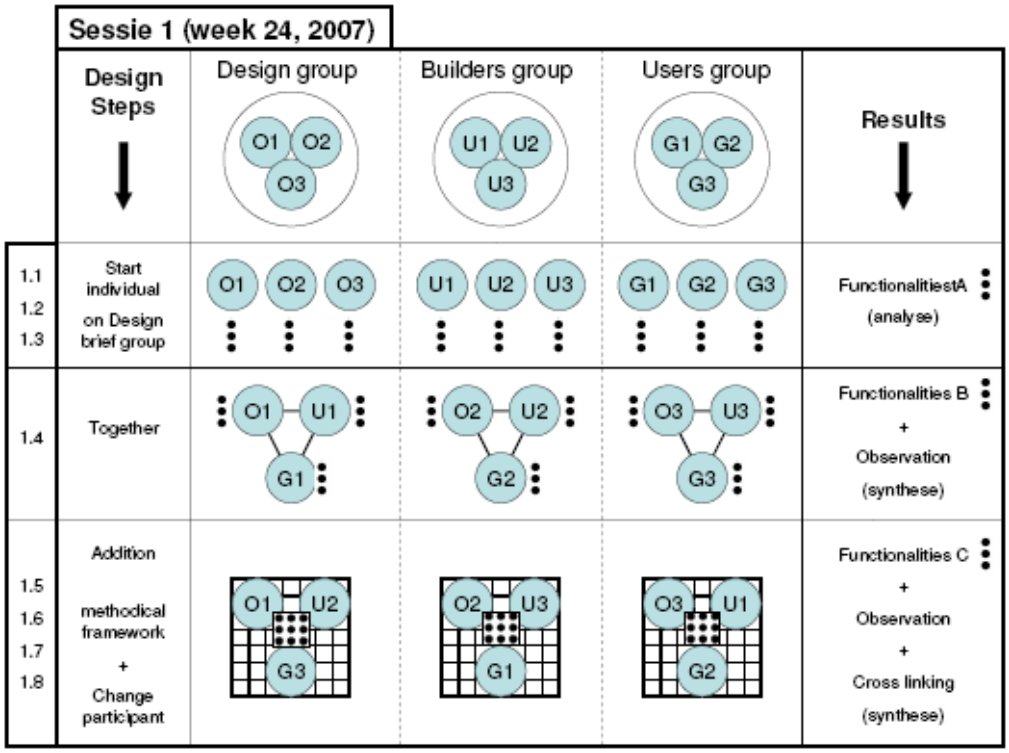

Figure 4. Set-up workshop series 1 Brakel-Atmos 2007

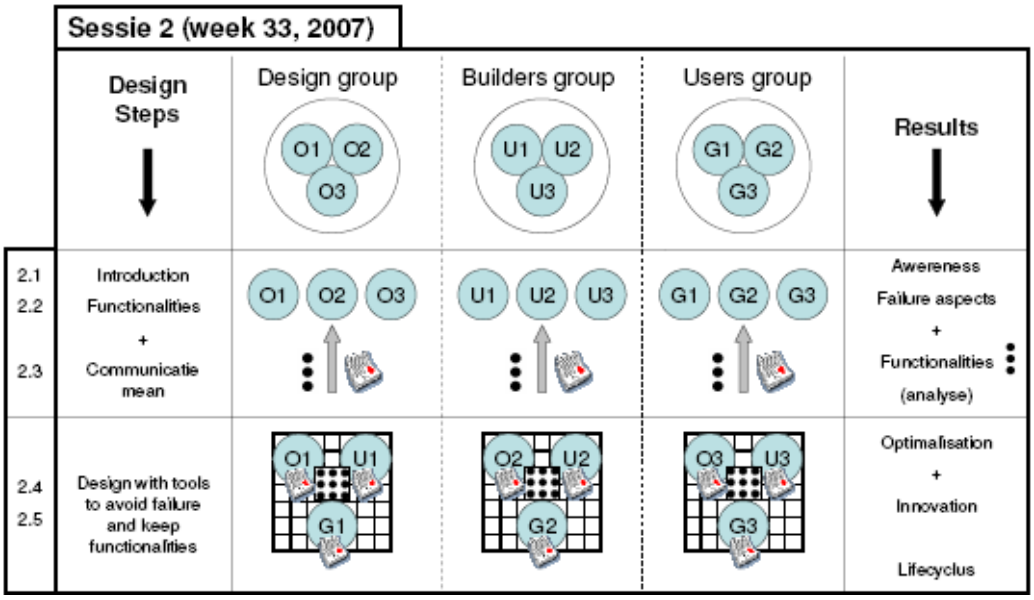

Figure 5. Set-up workshop series 2 Brakel-Atmos 2007

4. Results and discussion

The results of the questionnaires from workshops series 1 and 2 are given in figure 6 and 7. The overall average results of the questionnaires are given in figure 8.

Clearly it can be seen that especially the users (group 3 in figure 6) thought the use of the Morphological Overviews most positive for design improvement and communication. The builders group thought the approach more suited than the designers. Still both groups thought that the design process was improved by the use of morphological overviews. The positive rating of the users about the Morphological Overviews could be explained by the structural way the Morphological Overviews give information about the different aspects and sub-solutions related to the design task. Therefore the users get more inside information about the background of the developed design by the design team and can respond better on the designs by the Collaborative Design team.

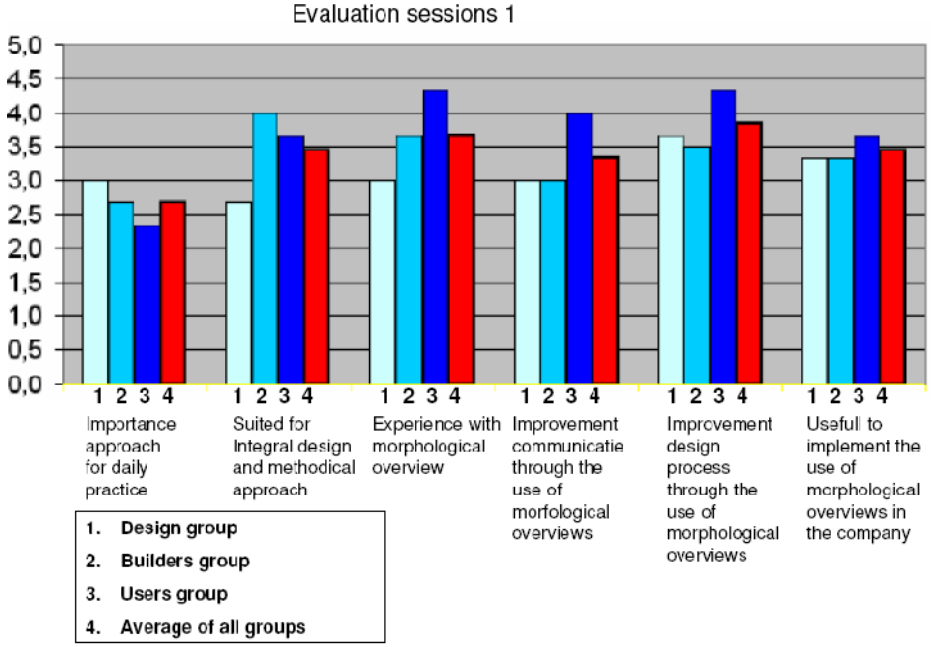

Figure 6. Results questionnaires series 1 Brakel-Atmos 2007

The difference between the builders and the designers in working with and appreciating the Morphological Overviews lies in their educational background and way of designing. The designers design in a more iterative way and less linear structured way than the builders. For the designers it is more obvious to work with a associative way of collecting and developing the different aspects and solutions related to the design task, especially at the beginning of the design. Builders are forced to work more structured because realizing and constructing the design means a more precise organisation of aspects and solutions to come to realization. Because of the different competences of designers and builders there view on the structuring method is different.

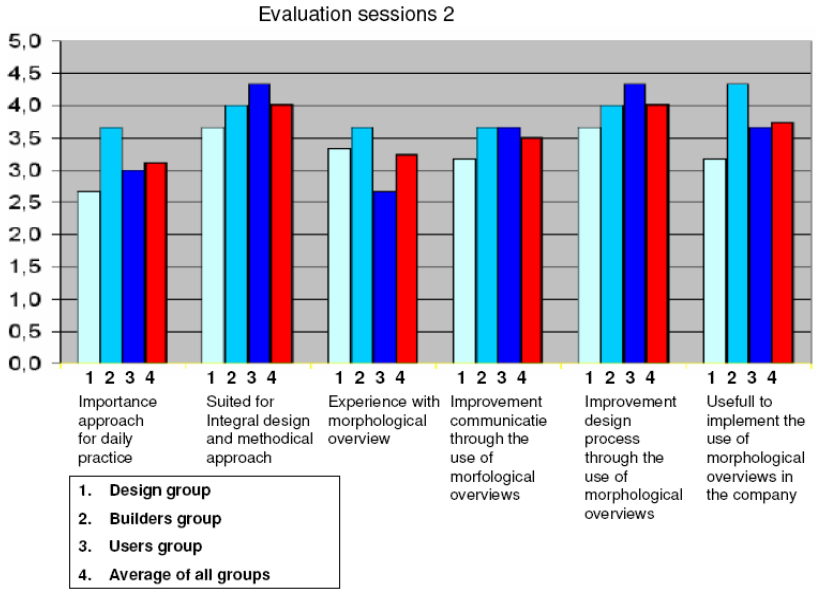

Figure 7. Results questionnaires series 2 Brakel-Atmos 2007

Alle the participants were positive about the influence of the use of the Morphological Overviews related to improvement of communication and design-proces; the explicit way of discussing, notating and developing the aspects and solutions could be addressed as the main reason.

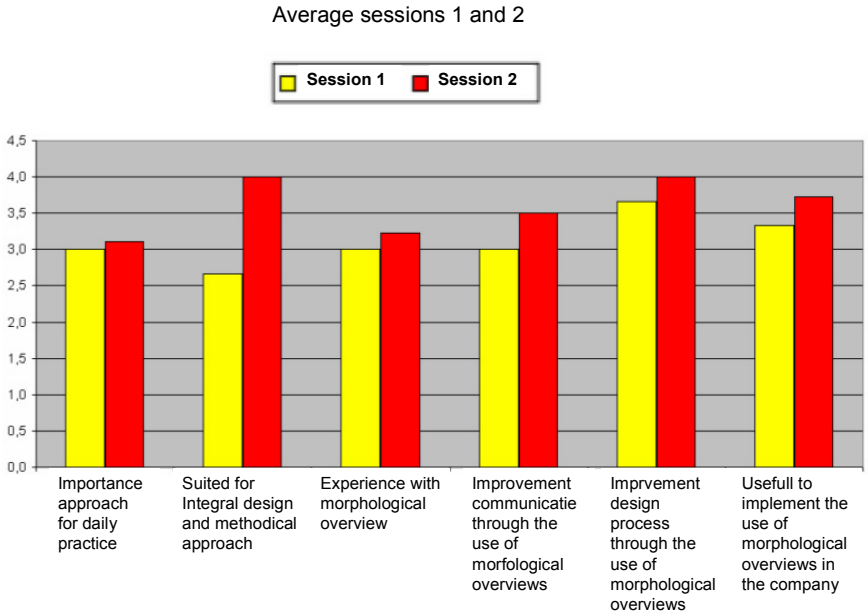

Figure 8. Average results questionnaires series 1&2 Brakel-Atmos 2007

The set-up of the workshop was split up in 2 days, with nine weeks in between. This is done for several reasons. The first reason is to give the professionals time to reflect on there collaboration and the use of the method. The second reason is that by using the same method twice shortly after each other in time possibilities in time for learning are minimal. The learning-effect by using the Morphological Overviews after 9 weeks again in a changed team-setting is more appropriate. This learning-effect from the perspective of the professional team-members can be seen in figure 7. Overall the ratings for the use of the Morphological Overviews of the sessions in week 33 are better than those of week 24. The time for reflection on the method itself but also the fact that the professionals got more acqaintant to the method and its possibilities are reasons for more appreciation of the method.

Also can be seen that the ratings from the design-group are overall lower than those of the builders and users. This could be explained by the more critical attitude by the designers towards a design method because of there design-experience and, as explained before, there different approach of designing due to there education.
As a resumé figure 8 gives a comparison of results of the workshops series 1 and 2 showing that participants were more positive about the set-up of the workshops and the use of morphological overviews after workshop series 2, than they were after the first workshops series.

5. Conclusion

Rerferring to the development criteria as named in chapter 3 the following findings can be identified. The lay-out for this workshop was positive for the participants for an In Company-setting because they could experience the different settings in the traditional way and with the use of the Morphological Overviews in a sequential way. The learning effect for the participants and the firm was effective due to the setting and feed-back in the second-day / cross appraisal tables. The different settings created a set-up for the participants to experience the influence of working in multi-disciplinary teams in relationship with the use of Morphological Overviews. The questionnaires gave a positive feed-back as well as the feed-back by the Company; they introduced the way of working and the use of Morphological Overviews for the research & development-group. The program was acceptable for the participants although there was too much focus and stress on the research-part.
Next step in the set-up change is to transform the setting for a non in-company environment and to work on a workshop-script to make the organisation and collaboration for it easier and less time-consuming. Also the influence on time in relationship to introduced support tools and type of design tasks has to be determined.
Related to the focus of the research on designers and builders, the setting of this specific In-company workshop with users was disturbing. To determine in the knowledge exchange between designers and builders as professionals in there field, the influence of the users should not be of influence in the research setting. The next workshop setting therefore should be in the Collaborative Design-setting were only architect and roofer are participating.
Although the number of participants in the workshops was rather small, we think because they were real experienced participants and because it was an in company setting, the results have real meaning for the added value of our proposed approach for practice. Based on the found and verified functionalities / needs an overview support can be generated as part of the developed IMD methodology by using morphological overviews. Through the use of this tool more insight in the knowledge exchange between different design team members can be generated. Requirements as specified with the help of the support tool will become clear and can be modified when the circumstances change. Within a wider range of the EURACTIVE ROOfer project the setting of workshops can be used for developing the Methodical Design Tools training-set up by the several Collaborative Design team-members for the Active Roof Design (EUR-ACTIVE ROOFer 2005).
The iterative approach will be further developed this year to come to the final Collaborive Design Workshop-setting which can be used to analyse the knowledge exchange between Architects and Roofers. The evaluation of this Descriptive Study 1 will be the stage of the Presriptive Study, were in a systematic way the final Collaborative Design Workshop is underpinned. This final Collaborative Design Workshop shall be used for the final research stage the Descriptive Study 2.

Acknowledgement

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